Climate Change and Flood Frequency
Some preliminary results for James River at Cartersville, VA

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Objective:

Climate change may increase annual precipitation in CARA region, which may in turn lead to increased stream flow and flooding. The objective of this study is to determine how flood frequency may change as a result of increased stream flow in precipitation in James River watershed.

Data:

Annual peak stream flow (P) recorded for the James River at Cartersville, VA (1889-2001)
Annual mean stream flow (S) recorded for the James River at Cartersville, VA (1889-2001)

Methodology:

Step 1:
Fit an appropriate distribution for P, and calculate the peak stream flow value for present 100-year flood (P_{100}).

Step 2:
Estimate a linear regression model for P and S:

$$P = \alpha + \beta S + \varepsilon$$

Assume that mean stream flow will increase by 20%*, use this model to generate a future peak flow series (P').
(* 20% increase in stream flow is what is predicted for the Susquehanna in MARA. I talked to Ray about applying the same increase to James River. He mentioned in another study he did with one of his students they found that stream flow changes in some other major rivers in the region, such as Potomac and James, are highly correlated to the changes in Susquehanna River. So using 20% might be a good start. Ray and I also talked about possibilities to run a water balance model for James River watershed to get a more accurate estimate on how mean stream flow will change with climate change.)

Step 3:
Fit the same distribution for P', and calculate the peak stream flow value for future 100-year flood (P'_{100}).

Step 4:
Calculate the future return interval for present 100-year flood (P_{100}) using the distribution function for P'.
Calculate present return interval for future 100-year flood (P'_{100}) using the distribution function for P.

Results

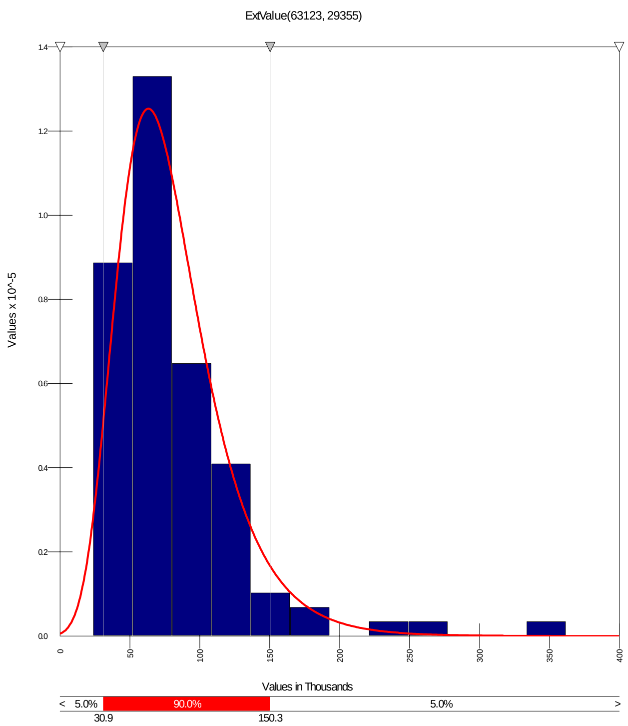
Step 1: Fit Distribution for P

A variety of distributions commonly used in hydrological frequency analysis have been used to fit P, including normal, log-normal, gamma, extreme value, Weibull and logistic distributions. The better fit ones include:

generalized extreme value, lognormal and gamma. The distribution recommended by Water Resources Council and used by most federal agencies is Log Pearson Type 3. However, it is not one of commonly used distribution outside hydrology, most existing computer software do not have procedures to estimate this particular type. I am writing a program to estimate Log Pearson 3 distribution, should have it done before the all-hands meeting in May. The fitting results are shown in figures 1-3, and the goodness of fit is summarized in Table 1.

Figure 1: Generalized Extreme Value (63123, 29355)

Distribution



P-P Plot

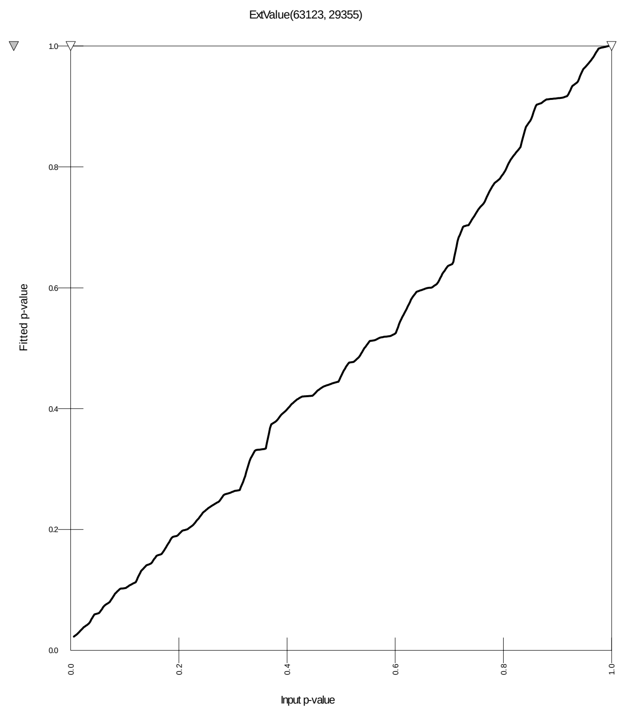
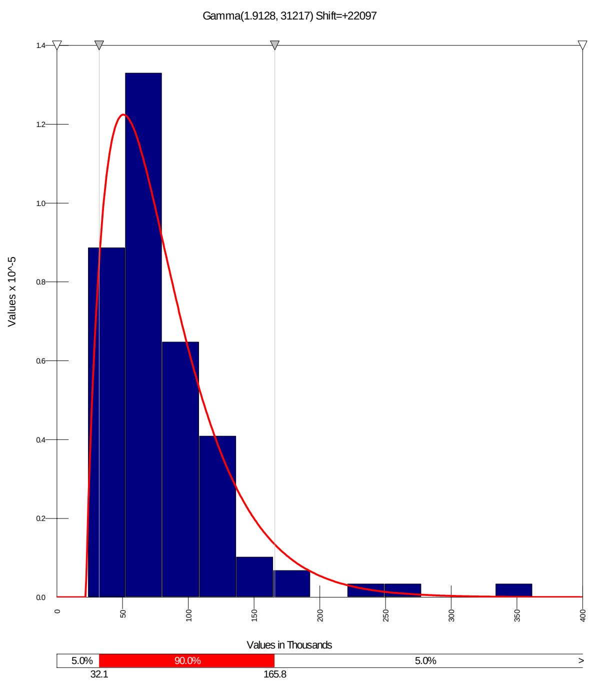


Figure 2: Gamma Distribution (1.91, 31217)

Distribution



P-P Plot

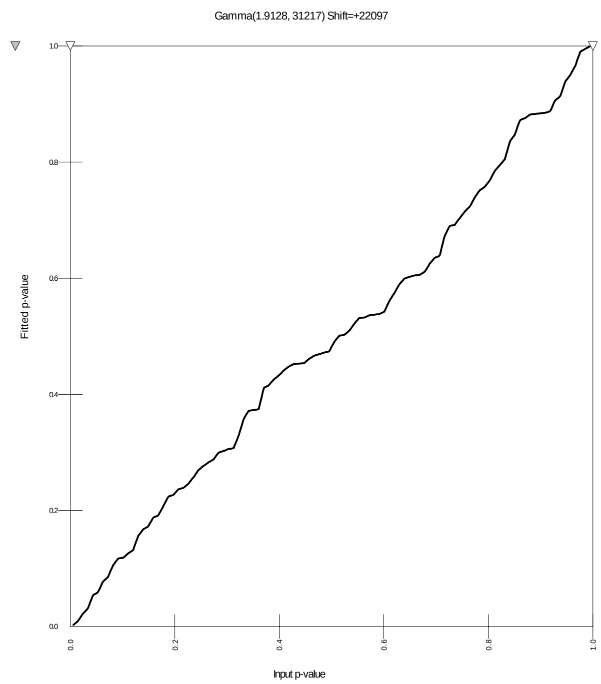
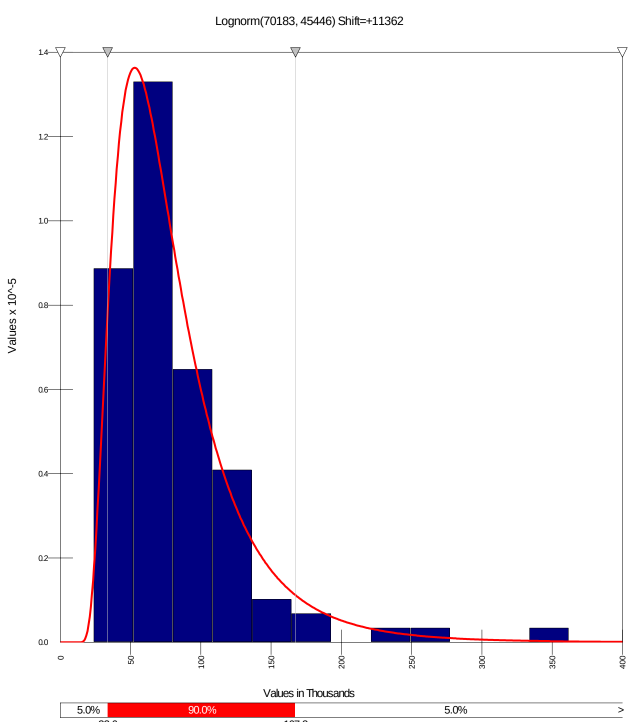


Figure 3: LogNormal Distribution (70183, 45446)

Distribution



P-P Plot

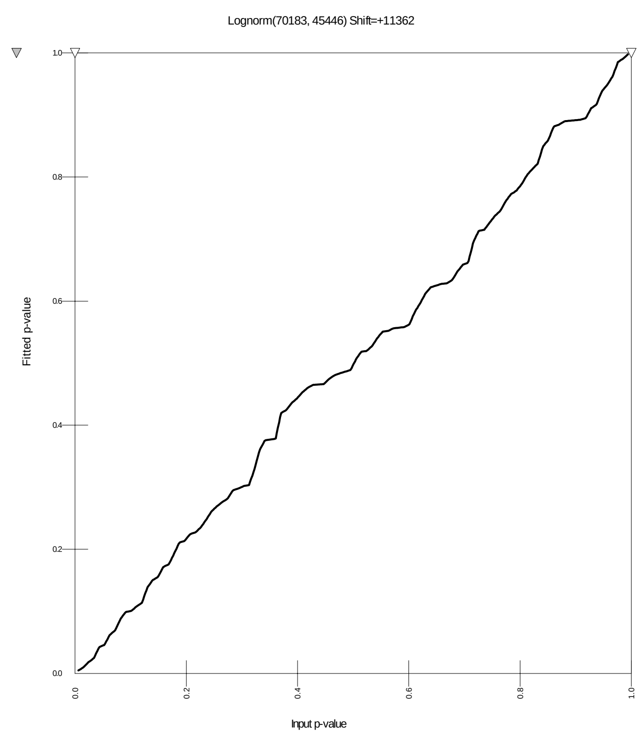


Table 1: Goodness of Fit for the Distributions

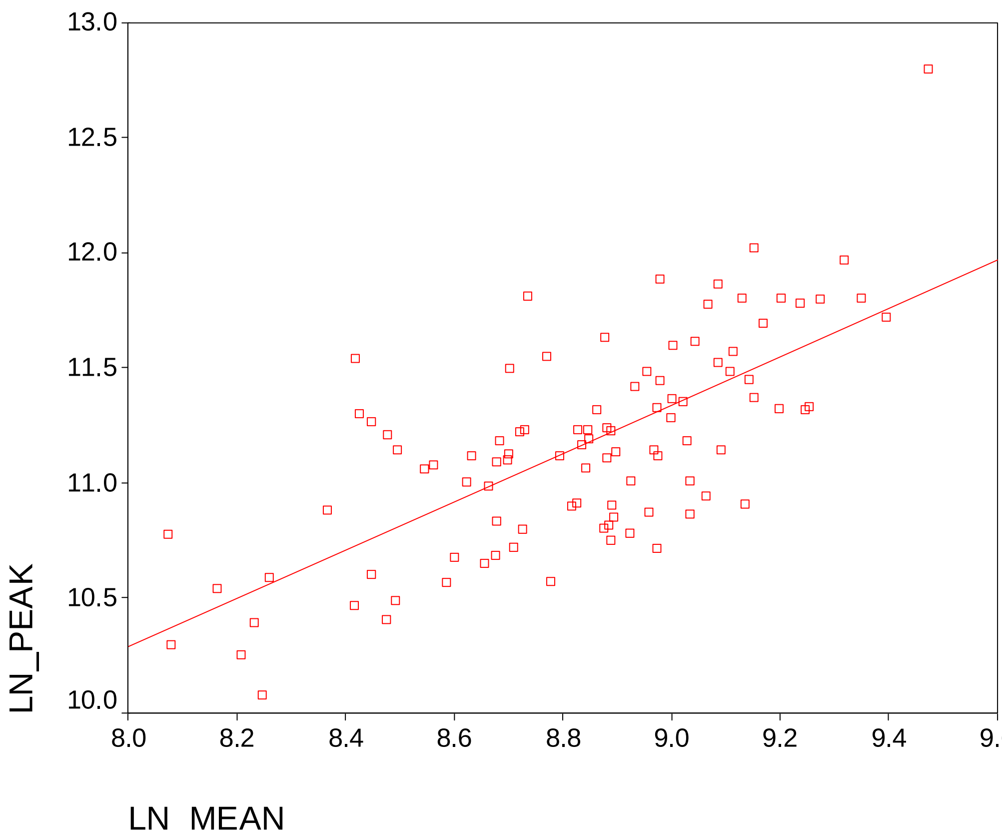
Distribution		Extreme Value	Lognormal	Gamma
Chi-square	Value	4.000	9.077	7.923
	P-value	0.9699	0.6148	0.7202
K-S	Value	0.6806	0.2437	0.5259
	P-value	$0.05 < p < 0.1$	N/A	N/A
A-D	Value	0.08106	0.05412	0.07312
	P-value	$0.05 < p < 0.1$	N/A	N/A

Step 2: Regression model

Since the distribution of both peak stream flow and mean stream flow is close to Lognormal, LN(P) and LN(S) are used in the regression model. The model is estimated as follows:

$$\mathrm{LN}(P) = 1.88 + 1.05\,\mathrm{LN}(S) + \varepsilon$$

$$\varepsilon = \mathrm{Normal}\ (0, 0.32)$$



$R^2=0.49$

Assuming 20% increase in mean stream flow, the future mean stream flow (S') is as follows:

$$S' = (1+0.2)\ S$$

Future peak stream flow (P') is:

$$LN(P') = 1.88 + 1.05(LN(S)+LN(1.2)) + \varepsilon$$

Step 3: Fit Distribution for P'

Similar procedure is conducted for P' as for P in step 1.

Step 4: Calculate peak stream flow and return interval for present and future 100-year flood.

Peak stream flow and return interval for present and future 100-year flood are calculated based on the three distributions that have relatively high goodness of fit. Results are presented in Table 2.

Table 2: Peak stream flow and return interval for present and future 100 year flood

Distribution	Peak Stream Flow (thousand cfs)	Present Return Interval (year)	Return Interval with Climate Change (year)
Extreme Value	198.2	100	51
	220.0	210	100
Log Normal	223.6	100	60
	246.8	171	100
Gamma	202.1	100	65
	219.6	161	100